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XXIV.—*Is there such a thing as Eozoon canadense?*
A Microgeological Investigation. By OTTO HAHN*.

I.

AT the time when the microscope began to find a more extended application in geology, came also the discovery of the "Dawn animal"—*Eozoon canadense*, as it has since been called. How great was the delight excited when it was supposed that at length the beginning of organic creation had been found! The Darwinian theory wanted the corner-stone; and there it was. As by a miracle, the primæval slime (*Urschleim*) had presented itself in a mass of serpentine limestone, which appeared just as the slime itself must have appeared; the film, microscopic tubes of 0.002 millim. diameter were still there wonderfully beautiful; and, as Carpenter says:—"a precise model of the most ancient animal of which we have any knowledge, notwithstanding the extreme softness and tenuity of its substance, is presented to us with a completeness which is scarcely even approached in any later fossil."

Who could help being pleased at seeing with his own eye this firstling of creation?

In a time of general excitement and enthusiasm it is difficult to preserve mental quietude. I have, however, attempted to

* Translated by W. S. Dallas, F.L.S., from a separate impression of the Memoir in the 'Württembergische naturwissenschaftliche Jahreshefte,' 1876.

do this as I commenced a work which concerned not only naturalists but men in general. Every one must feel that investigations into the history of Creation are family affairs. Hence the existence of some anxiety was not to be wondered at; but it excites more astonishment to see how easily many throw off their clothing and spring into the stream. The nature and method of my work may show that I did not commence with preconceptions.

A very great deal has already been written on the question. The results of my investigation have, I think, finally settled it. By my investigation it is established that there is no gigantic Foraminifer in serpentine limestone.

My investigations have shown that the most essential characters of the Foraminifera, the chambers and the test, are not there, but that we have to do with pure rock-formations, such as occur everywhere in serpentine. But if these two characters are wanting, there remain only the canal-systems; and these I have also recognized in gneiss, and at the same time discovered their real significance.

The zoologists may now furnish their reply. The material that I have made use of I will with pleasure place in their hands.

In order to let the opponents of the opinion maintained by me give full expression to their views, I will allow Dr. William Carpenter himself to speak. In his work 'The Microscope and its Revelations' (London, ed. 4, 1868) he describes and discusses *Eozoon* as follows:—

II.

"§ 396. A most remarkable fossil, referable to the Foraminiferal type, has been recently discovered in strata much older than the very earliest that were previously known to contain organic remains; and the determination of its real character may be regarded as one of the most interesting results of microscopic research. This fossil, which has received the name *Eozoon canadense*, is found in beds of serpentine limestone that occur near the base of the *Laurentian Formation** of Canada, which has its parallel in Europe in the Fundamental Gneiss of Bohemia and Bavaria and in the very earliest stratified rocks of Scandinavia and Scotland. These

* "This *Laurentian Formation* was first identified as a regular series of stratified rocks, underlying the equivalents not merely of the Silurian, but also of the Upper and Lower Cambrian systems of this country, by Sir William Logan, the accomplished Director of the Geological Survey of Canada."

beds are found in many parts to contain masses of considerable size, but usually of indeterminate form, disposed after the manner of an ancient coral-reef, and consisting of alternating layers—frequently numbering more than *fifty*—of carbonate of lime and serpentine (silicate of magnesia). The regularity of this alternation, and the fact that it presents itself also between other calcareous and siliceous minerals, having led to a suspicion that it had its origin in organic structure, thin sections of well-preserved specimens were submitted to microscopic examination by Dr. Dawson of Montreal, who at once recognized its Foraminiferal nature *; the *calcareous* layers presenting the characteristic appearances of true *shell*, so disposed as to form an irregularly chambered structure, and frequently traversed by systems of ramifying canals corresponding to those of *Calcarina*; whilst the *serpentinous* or other siliceous layers were regarded by him as having been formed by the infiltration of *silicates* in solution into the cavities originally occupied by the sarcode-body of the *animal*,—a process of whose occurrence at various geological periods, and also at the present time, abundant evidence has already been adduced. Although this determination has been called in question, on the ground that some resemblance to the supposed organic structure of *Eozoon* is presented by bodies of purely mineral origin †, yet, as it has not only been accepted by all those whose knowledge of Foraminiferal structure gives weight to their judgment, but has been fully confirmed by subsequent discoveries ‡, the author feels justified in here describing *Eozoon* as he believes it to have existed when it originally extended itself as an animal growth over vast areas of the sea-bottom in the Laurentian epoch§.

“§ 397. Whilst essentially belonging to the *Nummuline* group, in virtue of the fine tubulation of the shelly layers forming the ‘proper wall’ of its chambers, *Eozoon* is related to various types of recent Foraminifera in its other characters.

* “This recognition was due, as Dr. Dawson has explicitly stated in his original memoir (‘Quarterly Journal of the Geological Society,’ vol. xxi. p. 54) to his acquaintance not merely with the author’s [Dr. Carpenter’s] previous researches on the Minute Structure of the *Foraminifera*, but with the special characters presented by *Calcarina*, as exhibited in thin sections which had been transmitted to him by the author.”

† “See the Memoir of Profs. King and Rowney, in the Quart. Journ. Geol. Soc. vol. xxii. p. 185.”

· ‡ “See Dr. Dawson’s account of a specimen of *Eozoon* discovered in a homogeneous limestone, in Quart. Journ. Geol. Soc. vol. xxiii. p. 257.”

§ “For a fuller account of the results of the Author’s own study of *Eozoon*, and of the basis on which the above reconstruction is founded, see his Papers in Quart. Journ. Geol. Soc. vol. xxi. p. 59, and vol. xxii. p. 219, and in the ‘Intellectual Observer,’ vol. vii. (1865), p. 278.”

For in its indeterminate zoophytic mode of growth it agrees with *Polytrema*; in the incomplete separation of its chambers it has its parallel in *Carpenteria*; whilst in the high development of its intermediate skeleton and of the canal-system by which this is nourished, it finds its nearest representative in *Calcarina*. Its calcareous layers were so superposed one upon another, as to include between them a succession of 'storeys' of chambers; the chambers of each 'storey' usually opening one into another like apartments *en suite*; but being occasionally divided by complete *septa*. These *septa* are traversed by passages of communication between the chambers which they separate, resembling those which, in existing types, are occupied by *stolons* connecting together the segments of the sarcode-body. Each layer of shell consists of two finely tubulated or 'Nummuline' lamellæ, which form the boundaries of the chambers beneath and above, serving (so to speak) as the *ceiling* of the former, and as the *floor* of the latter; and of an intervening deposit of homogeneous shell-substance, which constitutes the 'intermediate skeleton.' The thickness of this interposed layer varies considerably in different parts of the same mass, being in general greatest near its base, and progressively diminishing towards its upper surface. The 'intermediate skeleton' is occasionally traversed by large passages, which seem to establish a connection between the successive layers of chambers; and it is penetrated by arborescent systems of canals, which are often distributed both so extensively and so minutely through its substance, as to leave very little of it without a branch.

"§ 398. Now in the fossilized condition in which *Eozoon* is most commonly found, not only the cavities of the chambers, but the canal-systems to their smallest ramifications, are filled up by the siliceous infiltration which has taken the place of the original sarcode-body; and thus, when a piece of this fossil is subject to the action of dilute acid, by which its calcareous portion is dissolved away, we obtain an *internal cast* of its chambers and the canal-system, which, though altogether dissimilar in *arrangement*, is essentially analogous in *character* to the 'internal casts' represented in figs. 258, 259. This cast presents us, therefore, with a *model* in hard serpentine of the soft sarcode-body which originally occupied the chambers, and extended itself into the ramifying canals of the calcareous shell; and, like that of *Polystomella*, it affords an even more satisfactory elucidation of the relations of these parts, than we could have gained from the study of the living organism. We see that each of the layers of serpentine forming the lower part of such a specimen is made

up of a number of coherent segments, which have only undergone a partial separation; these appear to have extended themselves horizontally without any definite limit; but have here and there developed new segments in a vertical direction, so as to give origin to new layers. In the spaces between these successive layers, which were originally occupied by calcareous shell, we see the 'internal casts' of the branching canal-system, which give us the exact models of the extensions of the sarcode-body that originally passed into them. But this is not all. In specimens in which the Nummuline layer constituting the 'proper wall' of the chambers was originally well preserved, and in which the decalcifying process has been carefully managed (so as not by too rapid evolution of carbonic-acid gas to disturb the arrangement of the serpentinous residuum), that layer is represented by a thin white film covering the exposed surfaces of the segments, the superficial aspect of which as well as its sectional view are shown in fig. 2. And when this layer is examined with a sufficient magnifying-power, it is found to consist of extremely minute needle-like fibres of serpentine, which sometimes stand upright, parallel, and almost in contact with each other, like the fibres of asbestos (so that the film which they form has been termed the 'asbestiform layer'), but which are frequently grouped in converging brush-like bundles, so as to be very close to each other in certain spots at the surface of the film, whilst widely separated in others. Now these fibres, which are less than 1-10,000th of an inch in diameter, are the 'internal casts' of the tubuli of the *Nummuline* layer (a precise parallel to them being presented in the 'internal cast' of a recent *Amphistegina* in the author's possession); and their arrangement presents all the varieties which have been described (§ 391) as existing in the shells of *Operculina*. Thus these delicate and beautiful siliceous fibres represent those *pseudopodial* threads of sarcode, which originally traversed the minutely tubular walls of the chambers; and a *precise model* of the most ancient animal of which we have any knowledge, notwithstanding the extreme softness and tenuity of its substance, is thus presented to us with a completeness which is scarcely even approached in any later fossil.

"§ 399. In the upper part of the 'decalcified' specimen shown in fig. 2, it is to be observed that the segments are confusedly heaped together, instead of being regularly arranged in layers, the *lamellated* mode of growth having given place to the *acervuline*. This change is by no means uncommon among Foraminifera; an irregular piling-together of the chambers being frequently met with in the later growth of

types whose earlier increase takes place upon some much more definite plan. After what fashion the *earliest* development of *Eozoon* took place we have at present no knowledge whatever; but in a *young* specimen which has been recently discovered, it is obvious that each successive 'storey' of chambers was limited by the closing-in of the shelly layer at its edges, so as to give to the entire fabric a definite form closely resembling that of a straightened *Peneroplis*. Thus it is obvious that the chief peculiarity of *Eozoon* lay in its capacity of *indefinite extension*; so that any single organism might attain a size comparable to that of a massive coral. Now this, it will be observed, is simply due to the fact that its increase by gemmation takes place *continuously*; the new segments successively budded-off remaining in connection with the original stock, instead of detaching themselves from it, as in Foraminifera generally. Thus the little *Globigerina* forms a shell of which the number of chambers never seems to increase beyond *ten*, any additional segments detaching themselves so as to form separate shells; but by the repetition of this multiplication the sea-bottom of large areas of the Atlantic Ocean at the present time has come to be covered with accumulations of *Globigerinæ*, which, if fossilized, would form beds of limestone not less massive than those which have had their origin in the growth of *Eozoon*. The difference between the two modes of increase may be compared to the difference between a plant and a tree. For in the plant the individual organism never attains any considerable size, its extension by gemmation being limited; though the aggregation of individuals produced by the detachment of its buds (as in a potato-field) may give rise to a mass of vegetation as great as that formed in the largest tree by the continuous putting forth of new buds."

III.

I commenced my investigations on three undoubtedly true Canadian Serpentine limestones:—

I. A specimen for which I am indebted to the kindness of Professor Hochstetter of Vienna. It came from Carpenter himself, and still bears his ticket. It is 95 millims. long and 50 millims. broad. It may be divided into three layers:—

1. Dolomite, 1-25 millims.; 2, pure pale-green noble serpentine (ophite), 25-35 millims.; 3, broad bands of limestone alternating with bands of serpentine 1 millim. broad, 35-55 millims.; then follows a granular formation.

From all the parts of the stone thin slices were taken. Carpenter regards layer 1 as the base.

Under the microscope layer 1 presents a whitish transparent amorphous matrix, and in this, traversing the stone in an oblique direction so that but little of the matrix is to be seen, hyaline crystals of dolomite, which, however, have their forms not sharply developed. They have innumerable yellow enclosures (picotite?). Sp. grav. 3.16, or that of dolomite. The crystals lose themselves irregularly in

Layer 2, the pure serpentinous mass. Under the microscope traversed by bands with parallel striation, which (in polarized light) immediately prove to be chrysotile. Sp. grav. 2.55. This layer is sharply discriminated from

Layer 3, the alternating layer. First a limestone band 5 milims. broad, then a serpentine band of equal breadth, and so on. Limestone and serpentine bands, but constantly becoming narrower, now alternate; they are parallel, elongated, and cut off perpendicularly at the lateral ends. The limestone bands effervesce with dilute hydrochloric acid and *dissolve rapidly and completely*. They therefore contain no silica. Sp. grav. 2.60. Distributed in the limestone, and more rarely in the serpentinous mass, there are round and six-sided hyaline crystals. These are arragonite. Here also are the canal- or branching-systems. The latter, however, are not uniformly distributed in the limestone, but only in particular granules (individuals). I have found ten canal-systems to 7 cubic centims. The mass of these systems is white by direct, and light brown by transmitted light. In many places the origin of the canal-systems from the spot where the arragonite crystals are may be distinctly recognized. They are never continued into the chambers, and, indeed, have no relation at all to these. Nay, they even thicken towards them in their stolons. Their form I take to be well-known.

What Carpenter calls the "film," is a chrysotile layer around the serpentine. This layer I have observed in nearly all ophites. The aciculæ are not tubes (even under the highest magnifying-powers they contain no filling mass), but *crystals*.

Layer 4. Now follows granular structure. The serpentinous mass is in part not even yet quite homogeneous. *We distinctly see granules with olivine-polarization and cracks, even traces of a lamination*. The passages cease both towards the sides and upwards. The arragonites are still present; but instead of the canal-systems there are only fissures round about the arragonite granules, filled with the same milk-white mass of which the canal-systems in No. 3 consist.

II. Hand-specimen in the collection of the University of Tübingen. 50 millims. long, 40 millims. broad.

1-10 millims. serpentine alternating with threads of chry-

sotile ; 10–25 millims. serpentine as in I. ; 25–28 millims. a broad limestone band ; 29–40 millims. serpentine alternating with limestone in nearly parallel bands, as in I. Seen from the side, the bands lie in oblique lines ; the stone is therefore probably composed of undulated layers.

The limestone varies from hyaline to milk-white ; both colours are seen in bands side by side. The cleavages are distinctly visible. The arragonite forms small points. The remaining 10 millims. are of granular structure.

In polarized light the chrysotile at once catches the eye ; but it is only necessary to make a rough section, and then the white needles project from the matrix. Under the microscope these chrysotile threads are seen almost everywhere on the edges of the serpentine, but also in the limestone at its point of contact with the serpentine, generally perpendicular to both.

III. Hand-specimen in the collection of the University of Tübingen, presented thereto by Professor von Hochstetter. 100 millims. long, 60 millims. broad. Has a round serpentine spot at one end. This circle is surrounded by alternate layers of serpentine and limestone. At the opposite side there is likewise a similar round spot. Between the two there is a paler band (also limestone), bent so that the white appears like a note of interrogation. At the end dolomite. Sp. grav. probably as in I. 3.

In this specimen there are limestone fragments in the serpentine passages. Several canal-systems may be seen even with a power of 25 diameters ; in some it may be distinctly perceived that they start from the disseminated arragonite.

What is particularly remarkable in this specimen is that the limestone forms layers with canal-systems only in small surfaces ; by far the greater part is granular with distinct fluidal structure, which can only be the consequence of a strong pressure. In consequence of this the layers also are broken up into spherical masses and mixed up together. In many places there are black points in the limestone ; these are very probably graphite.

What follows applies to all the three specimens :—

The serpentine undoubtedly originated from olivine which got into a mass of limestone while the latter was still soft. When the decomposition took place quietly and no pressure intervened, the serpentine would at first retain the form of the olivine, but by further decomposition the soft granule would first of all become squeezed flatter in consequence of the pressure exerted by the overlying mass. If no way of escape presented itself, or if an opposing pressure occurred

from the sides, cylinders with an elliptical section would be formed, and by further pressure finally strata (layers) in the limestone mass. But if, as in specimen III., unequal pressure occurred, the layers must have been broken up and torn to pieces; but the parts would then, where they hardened, show granular structure in their section. It cannot be asserted that the intervening calcareous mass was hardened or even present before the serpentine; otherwise the fluidal structure would no longer be explicable.

The canal-systems are of very different diameter; they also differ with regard to their distribution and form. They consist of carbonate of lime. Nowhere do we see around them an envelope like shell-substance, but they rather vanish into the surrounding material.

I also investigated:—

IV. Serpentine limestone from the Bayerische Wald. The sequence is limestone, limestone with graphite, limestone with serpentine, granular as in III., serpentine, limestone with serpentine, limestone with graphite. Distinct chrysotile layers round the serpentine grains. No trace of canal-systems.

V. Serpentine limestone from Krummau (Bohemia), from Professor von Hochstetter. 1. A similar specimen treated with acid.

The limestone is coloured grey by black enclosures. A large, much divided serpentine layer. The serpentine is enveloped by a layer of chrysotile, which appears as a fine white line. No canal-systems.

VI. Another serpentine limestone will be mentioned below.

All the serpentine limestones at command, especially from Elba and Lissiz, were examined. Much as the latter resembles II., no trace of the canal-systems could be found, but there were chrysotile shells. With regard to the latter, I refer the reader to Draschke, in Tschermak's 'Mineralogische Mittheilungen,' 1871, Heft i. p. 1.

Further, about thirty serpentines, from the pseudomorphic crystals of the Snarum to the pure sedimentary rock, and, lastly, all the primary limestones at my disposal were examined, and, finally, about twenty gneisses. In that of Mont Blanc I recognized the canal-systems.

IV.

I regarded it as the simplest course, with respect to the description of the *Eozoon*-rock, to allow its first investigator, if not its discoverer, to speak. Little has been added to his description of *Eozoon canadense*. Gümbel thought he detected

wart-like superficial processes. Max Schultze states that after the calcination of the rock the canal-systems were coloured black; and from this he concludes that their contents were of organic nature.

I could only repeat what is well-known, if I were to reproduce here the present position of the controversy. Zirkel has given a thorough representation of the contradictory opinions ('Die mikroskopische Beschaffenheit der Mineralien und Gesteine,' Leipzig, 1873, p. 313). As regards Max Schultze, I may refer the reader to the 'Verhandlungen des naturhistorischen Vereins der Preussischen Rheinlande und Westphalens,' Jahrg. xxx. p. 164, unfortunately an incomplete work of the celebrated naturalist.

There are consequently two opinions. One maintains the organic nature of *Eozoon*; the other disputes it. The former supports itself upon analogous facts in the animal kingdom, both extinct and living. The latter holds that it can also cite analogies in favour of the assumption of peculiar rock-formations. Few leave the question open.

I thought it best to adopt the following mode of investigation.

I started from the proposition that for every part of a rock the *presumption* is in favour of mere rock-formation. If the organic nature of a portion of the rock is affirmed, the *onus probandi* lies upon those who make the assertion, and, until full proof to the contrary, the presumption remains in force.

But in the present case we stand immediately in face of a great difficulty. What are the characters of an organic being? The same structure, and especially the same structures *together* (as is admitted by Carpenter and his allies), occur neither in extinct nor in living organic creatures; but it is rather stated that the individual parts of the *Eozoon*-structure are only to be recognized in *different* kinds of Foraminifera.

This circumstance alone makes the proof very doubtful. But to this must be added the further fact that the zoologists, and especially the best of them, are least inclined, and indeed least in a position, to know and test all existing rock-structures. The position of the geologist is therefore all the more unfavourable. His proofs are scarcely considered; and even otherwise it is difficult to get their value as proof duly estimated; whilst the zoologist is in the happy position of being able to throw into the scale the Brennus's sword of authority, especially when the microscope is in question.

The position of the two can only be equalized if it be admitted that mere analogy is incapable of furnishing the proof of the organic origin of *Eozoon*; and that, further, no part of the

supposed organism can be recognized as mere rock-structure. It is only if all the essential characters of the Foraminifer, and indeed each for itself, are no mere rock-structures, that the proof from analogy is carried at least to a high degree of probability. But if the inorganic nature of only one is proved, the chain of evidence is broken.

From all this the course of investigation becomes a matter of necessity. All existing serpentine limestones (ophicalcites), all serpentines and primary limestones by themselves, and, further, also the minerals occurring under certain circumstances in the serpentine limestone, must be investigated with respect to their nature and their relations to the serpentine limestone. But when this is done, a large field opens to the geologist. Now the question is, do the *Eozoon*-structures occur in any other rock or not, whether with all the characters together or at least some of them? Upon this it becomes his duty to examine microscopically as to this point all primary and metamorphic rocks, nay, even the rocks of the whole sedimentary series. I have followed the course indicated, and then, and not before, allowed myself to form a judgment upon the zoological facts which had been advanced. In what follows I shall undertake, first, the criticism of the geological, then of the mineralogical, and, lastly, of the zoological facts.

1. *The Geological Facts.*

The *Eozoon*-structures occur in lenticular or spheroidal nodules of serpentine limestone in the limestone of the Laurentian formation of Canada. The limestones belong to gneiss strata, the earliest sedimentary rocks. They are mere enclosures. Are they merely imbedded in the limestone, and therefore formed before it, or were they produced simultaneously with it? This question can be decided only on the spot. It is most probable that they were imbedded as ready-formed nodules; but this is not necessary. If the serpentine-mass was, as it must have been at the time of the formation of the *Eozoon*, still in a fluid state, it must also have found other cavities in the limestone, and have filled these. But we have no account of any such cavities. Hence the first supposition is the more probable.

Eozoon is said to occur not only in Canada, but also in the most various parts of the earth. Gümbel has found it in the Bayerische Wald, Hochstetter in Bohemia (Krumman), and Pusgrewski in Finland. I have examined some of the hand-specimens of the two first named and found in them no *Eozoon*-structures, or at least not all the described characters together.

In these and a great number of serpentine limestones there were everywhere the alternating layers of serpentine and limestone, but nowhere the so-called canal-systems of the Canadian *Eozoon*.

Upon *this*, however, I lay no great weight after the results subsequently obtained. Where these canal-systems do not occur, there is, as I must mention at once, no trace of probability for an organic structure.

According to a communication from King and Rowney, ophticalcites occur even in the Lias of Scotland.

From the preceding statements it follows that even with respect to the question whether *Eozoon*-structures exist, we must carefully and in the first place ascertain quite clearly what are the essential characters of *Eozoon*. If the investigator lays especial stress upon the chambers or alternating layers of serpentine and limestone, he will find *Eozoon*-structures wherever serpentine occurs. I have such specimens out of mineral deposits. I have a specimen of serpentine limestone in which the two layers appear exactly in the same form as in the Canadian specimens, but are 2 centims. instead of 1.5 millim. in thickness.

I have, in the first place, to refer to the formation of serpentine.

Serpentine is not an original, but a metamorphic rock. As is well known, there is no rock which is so certainly the result of metamorphism and can be derived from so many minerals as serpentine; Gustav Rose has shown that it may originate from augite, hornblende, pyrope, and spinel. It probably originates in the greatest masses from olivine, and, indeed, by the access of water. But everywhere it occurs in association with limestone; and so the alternate layers of the two substances cannot be in the least surprising.

I have investigated an immense number of serpentines, and always found that they are products of metamorphism. Take the Snarum pseudomorphs after olivine, in the interpretation of which Prof. Quenstedt first proved his mastership. In these, olivine grains, still undecomposed, lie in the olivine crystal, which is now serpentine. The crystalline form has persisted; the olivine has been converted by access of water into serpentine.

The basalts of the Swabian Alb (especially those of Eisenrüttel) display in every hand-specimen the distinct picture of the serpentinization of olivine. The Karfenbühl, near Dettingen, consists for the most part of such serpentine. In the Canadian serpentine limestone also olivine grains are to be detected with fragments of limestone in the serpentine. By

this, of course, the filling of the chambers would immediately be got rid of as an impossibility ; but it might be objected that here the olivine grains are not quite certain, and the serpentine bands, which are vermiform in their section, cannot be so easily explained away.

But at the conclusion of my investigation I was so fortunate as to obtain two specimens of serpentine limestone which remove all doubts. Their derivation is unknown to me ; but this does not affect the matter ; at any rate, they are not from Canada.

These specimens show in their interior exactly the same serpentine layers as the Canadian ones, and in section exactly the same chambers ; but in the middle of the chambers are the *olivine grains*, which still polarize splendidly (red and green). In the rock, where the decomposition has not advanced so far, there are still round, oval, and angular fragments, and, finally, I found the cleavage-planes with the angle of olivine.

That olivine here also is the parent of serpentine is indubitable ; but at the same time it is shown how the decomposition of the olivine took place. The olivine changed from without into a gelatinous mass. This, as is well-known, happens in areas ; and hence, as chrysotile-threads form at the limits of the areas, the serpentine has afterwards the appearance of chambers. The decomposition may thus be followed piece by piece, and through all stages up to the structure of the Canadian specimens. The gelatinous mass no longer polarizes ; but the newly formed serpentine mass polarizes in the same fashion as all aggregated rocks ; a new crystal-formation has commenced.

Thus in these two specimens the serpentine structure may be traced in accordance with the form that it took on in correspondence with the action of the decomposing water, from the imbedded and still perfectly preserved olivine crystal with distinct cleavage-planes to the (formerly fluid) serpentine mass. Conceive the olivine crystals gradually converted into a gelatinous matter. The latter must have deposited itself *uniformly* in the calcareous mass, which was also still soft, and consequently must have become round. Now the slightest vertical pressure sufficed to give the gelatinous spheres a cylindrical or lenticular form ; their section will always be a line, like that of the Canadian *Eozoon*-rock. The intermediate passages also occur. Further, everywhere on the serpentine, in places at the points of contact with the limestone, there is the "film" or asbestos-layer, *i. e.* a crystallized layer with needles.

In these specimens, therefore, we have the proof that the

chambers, the passages, and the "film" of the "giant Foraminifer" originated from olivine crystals; therefore they are pure *mineral structures*.

I have observed the same things even in the Canadian rock; only in it the olivines are not so fresh as in the former. But as the serpentine mass occurs in exactly the same form as there on the outer surface of the hand-specimen, the conclusion that both were originally in the same state, is perfectly justifiable.

The calcareous layers occur in serpentine rocks which certainly contain no *Eozoon*-structure. There is nothing in favour of their owing their origin to a Foraminiferous test.

The question will now be raised, Do the *canal-systems* of the Canadian rock also exist in the two hand-specimens? No; with the exception of *one* spot in a green mass which does not polarize. It might, however, possibly be that the mass of limestone was over- or underlying, and that the canal-system occurred in the limestone. But this very spot also exhibits the clear points (disseminated arragonite), with which, according to my observations, the presence of the canal-system is always associated, even in the Canadian rock. In all the rest of the rock, in the thin sections, there is no arragonite and no canal-system.

Let us now draw the direct conclusions:—

During the separation of the arragonite from the limestone, water, or some other fluid containing lime, remained behind. By existing pressure this penetrated into the soft limestone mass in exactly the same way that every fluid penetrates into another, denser one, in ramifications.

This may be regarded as hypothesis, although the explanation is not far-fetched. It may be objected that this process must also occur elsewhere.

But I have further been able to demonstrate these canal-systems in the gneiss of Mont Blanc and the Schwarzwald—nay, even in the syenite of the Plauenscher Grunde (Saxony) and in the syenite of the Schwarzwald. I have observed them in about *thirty thin sections of these under crossed Nicols*. It is only thus that they make their appearance in the transparent felspar and limestone, but then as beautifully as in the Canadian specimens.

Thus from this side also, by the demonstration of a perfectly similar phenomenon in other rock, we obtain an explanation of the canal-systems.

And thus the last character of the "giant Foraminifer" is got rid of—a character, however, which could not alone furnish the proof of the organic nature of the *Eozoon*-structures.

With this I might conclude my work. But as I do not wish to fall short even in the smallest degree with respect to the evidence in contradiction and its foundation, I pass on to

2. The Mineralogical Facts.

In the formation of the Canadian *Eozoon*-serpentines only three minerals seem at the first glance to take part—dolomite, serpentine, and limestone.

On closer investigation, however, other minerals occurred :—

No. II. has superiorly a *chrysotile band*, 7 millims. in breadth, which is frequently repeated in the serpentine. Whenever I ground the surface of the plate rather rough, a thread of silvery lustre appeared everywhere around the serpentine bands ; and this was not merely asbestos-like, but actually asbestos, *namely chrysotile*.

Besides *chrysotile*, *arragonite* occurs in disseminated clear grains, and even in six-sided prisms.

The *arragonite* is surrounded by the same mass that forms the canal-systems ; this is white by direct, brown by transmitted light. When treated with acid, *it dissolves at the same time with the limestone*. If the canal-systems were connected with the chambers and, as Carpenter thinks, injected with serpentine-mass from the latter, *they would not dissolve at all in acid* ; they must be serpentine and show the colour and polarization of serpentine. Where there are serpentine grains, the same white mass passes into the fissures surrounding the serpentine grain. It is only in the alternating layers that the canal-systems are in the limestone ; and frequently their origin on the disseminated *arragonite* grains may be distinctly detected.

Hence we get the following as to the formation of the stone :—

The serpentine grains were originally olivine. During their decomposition they swelled up, and in consequence burst up the surrounding limestone, when the fluid *white* calcareous mass entered into the fissure. But where the limestone mass was still soft when the serpentine mass swelled up in it, either the extending serpentine mass itself pressed the white calcareous fluid into the limestone, when the canal-systems were formed, or a pressure was produced upon the whole mass, and then the same effect occurred, only the immediate cause was different.

It was undoubtedly either a pressure from within, caused by the decomposing olivine grains, or one from without upon the whole mass, that produced the canal-systems. This is proved even by their form. In the first place, they are quite irregular

in their arrangement. Where they are arranged somewhat in a spiral line, this is to be ascribed to the circumstance that the calcareous layer itself, from which they originated, had already a circular or spiral arrangement produced by pressure, as is shown in specimen III. This, however, is accidental. Usually they are irregular in arrangement, position, and form. I have observed such a canal under a power of 750 diameters. No trace of calcareous envelope, or of tubular form; the picture is rather that of a fissure; the canal is quite irregular, thicker or thinner, and in a zigzag direction.

In conclusion I have a remark to make with regard to the limestone. This consists, like all primary limestones, of separate individuals, distinctly separated from each other by their lamination and a line, and in polarized light fully show themselves to be individuals by their different position. Many individuals have the *twin cleavage-planes produced by pressure*. I have here to refer to the discovery of Prof. von Reusch, who produced the cleavage-planes by concussion. This phenomenon of itself indicates powerful pressure undergone by the mass *after its solidification*. Curiously enough there are no canal-systems in the limestone individuals with twin lamellæ. *Moreover a canal-system generally does not extend beyond one limestone individual*. This is easily explained. The fluid could penetrate only into a still soft individual; it must therefore have found a limit at the next somewhat more hardened one. It must not be overlooked that the canals, when they strike upon the serpentine mass or on neighbouring individuals, become thicker, and terminate with a kind of knob, the most certain evidence of a mass pushing from behind and here coming to a stop.

The canal-systems occur only where the serpentine mass is elongated, transparent, and yellowish; therefore only where the whole mass was visibly completely metamorphosed, softened, in fact, into a pasty fluid, and pressed while still in this state; for only thus could the original olivine-forms be converted into serpentine layers. Thus also are explained the vertical lines in which the serpentine layers laterally strike against a narrow limestone layer.

Thus, then, there does not remain much to be said about

3. *The Zoological Facts.*

If we glance back over the previous results we have, for every part of the *Eozoon* (the chambers, the walls with columns, the film, the intermediate mass with large passages, as well as the canal-systems), not only an adequate geologico-mineralogical explanation, but also the same phenomena in rocks in which no one will speak of *Eozoon*-structure, unless,

indeed, the canal-systems in gneiss must of themselves alone be explained as of organic origin. I admit that I was for a moment doubtful whether analogy for these structures in gneiss might not be found in the sponges. I had, however, to renounce this charming idea when I found that the canal-systems consisted of quartz which traversed the felspar. Here I would recommend the further examination of this hitherto unobserved phenomenon; I believe that it throws a new light upon the formation of gneiss.

It certainly does not conduce to exactness of inference if, for the organic creature that is supposed to have been discovered, we can find no complete analogue, and, for its separate parts, again at least no exactly similar part in another creature. *Polytrema* is regular. With the *Acervulinae*, with which Max Schultze arranges *Eozoon*, it has nothing in common except irregularity—in such matters a resemblance of very doubtful value. The *Calcarinae* have quite regularly arranged canal-systems. The circumstance that our zoologists are accustomed to preparations very different from rocks, and that they have a preconceived notion that any symmetrical structure cannot be inorganic, contributed not a little to the confusion. I need only refer to the microscopic picture of the pitchstone of Arran. But no rock is more deceptive in this respect than serpentine. This greenish yellow transparent mass, with its peculiar trembling lustre (caused by hyaline crystals) looks so deceptively like sarcode, that it must not be taken amiss of a zoologist if he is unable to tear himself free from the ideas that press upon him at the first glance. If now, unfortunately, the worm-like form is superadded, if the sarcode mass is further clothed with an asbestos layer, and, lastly, we see further “dentine-” and canal- or branch-systems, then it is too much. Can it surprise us if another finds verrucose processes? And yet nothing but illusion. Only a small amount of quiet observation would at once have led back to the truth. The observer must in fact have been puzzled at once by the single fact that the canal-systems do not consist of serpentine mass; and this a glance into the microscope with polarized light would immediately have shown. The canal-systems always penetrate the chamber-walls of the *Operculinae*. Here there is no trace of this, but rather a completely different filling mass in the two. Nay a single olivine grain or calcareous fragment in a chamber of *Eozoon* must fairly raise the question, How can an olivine grain get into the chamber of a Foraminifer? On more careful observation, moreover, chambers existing quite alone (*i. e.* grains) would have been found. The chrysotile shell also is not regularly present; where

present it cannot be mistaken by the geologist. But even as to this shell the zoologists underwent a *deceptio visus*.

The serpentine mass is always round. If a chamber be cut in any way except equatorially, the limestone mass of course projects over the serpentine mass, and the one shines through the other; the inner angle of section now projects itself as a line upon the surface of section; and thus is produced the appearance of a shell, especially if asbestos needles are seated upon the margin of the limestone, and partially project beyond it. We may easily convince ourselves of the illusion at sinuations of the serpentine mass, as also in purely equatorial sections.

Chrysotile layers are to be found in every serpentine. The weathering of serpentine takes place in divisions; and hence the delusive walls.

How, it must further be asked, should a canal-system make a dead stop before a crystalline individual? If the calcareous shell were originally there, the canal-systems must have traversed it in accordance with the law of organic structure. If crystal-formation, or any other condition which destroyed the canal-systems, afterwards occurred, this altered nothing in the *original arrangement of the canal-systems*; they could at the utmost disappear here and there, and, indeed, in separate crystalline individuals, but must have been continued in the next individual. *But there is nothing of this kind.* The separate systems are rather completely limited in crystalline individuals, from which it follows that the crystalline mass, nay, the limestone, was in existence before the canal-system. These crystalline individuals are only commencements of crystal-formation. And finally we must ask why are there never canal-systems in twin crystals? For the simple reason that these had become hard, while the other parts were still soft.

As a last thing I will notice how improbable was the preservation of the structures in the rock which bears in it such distinct traces of having suffered violence.

I fancy from these statements of fact that the *Eozoon*, after a brief but brilliant existence, is buried. It was indeed a "dawn animal."

In conclusion, I offer my honoured teacher Prof. von Quenstedt, of Tübingen, and Dr. von Hochstetter, of Vienna, my best thanks for the liberality with which they have furnished me with material for my investigation. Nor can I omit to commend the admirable thin rock-sections of Mr. R. Fues, of Berlin.

My investigations were made with an excellent new Hartnack's instrument (VII. A), and with an English one by Baker, of London.